COS 316 Precept: Concurrency Part 2

Precept Objectives

- Review Go concurrency concepts (needed for "connection pool" assignment)
- Gain more practice with Go and concurrency concepts
  - `RWMutex`
  - Condition Variables:
    - `sync.L.Lock` and `sync.L.Unlock`
    - `sync.Cond` and `Signal`, `Wait`, `Broadcast`
- Understand the Dining Philosophers problem

Review Mutexes

- Consider the following example

  https://play.golang.org/p/LAfTM5gO-EJ

RWMutex

- An [`RWMutex`] - a reader+writer mutual exclusion lock.
- For an addressable `RWMutex` value `mu` (`mu sync.RWMutex`)
  - data writers
    - acquire the write lock of `mu` through `mu.Lock()` method calls
    - release the write lock of `mu` through `mu.Unlock`
  - data readers
    - acquire the read lock of `mu` through `mu.RLock()` method calls.
    - release the read lock of `mu` through `mu.RUnlock`
- `Why do we want different types of locks for writing vs reading?`
- `Modify the example (from previous slide) to use RWMutex`

Notifications

- `sync.Mutex` and `sync.RWMutex` values can also be used to implement *notifications*
    - Note - not recommended - for illustrative purposes only!
- What gets printed first? Why?

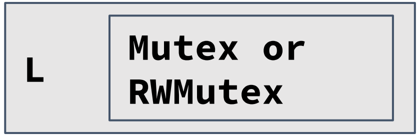
```
func main() {
	var mu sync.Mutex
	mu.Lock()
	go func() {
		time.Sleep(time.Second)
		fmt.Println("COS")
		mu.Unlock()
	}()
	mu.Lock()
	fmt.Println("316")
}
```

- https://play.golang.org/p/cw_os3bQfAG

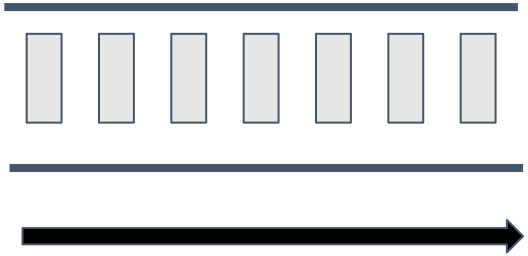
Condition Variables - `sync.Cond`

- `sync.Cond` type - provides an efficient way to send notifications among goroutines

- `sync.Cond` value holds a `sync.Locker` field with name `L` - field value is of type `*sync.Mutex` or `*sync.RWMutex`
    - E.g.:
        - `cond := sync.NewCond(&sync.Mutex{})`
        - `cond.L.Lock()`
        - `cond.L.UnLock()`



- `sync.Cond` value holds a FIFO queue of waiting goroutines



- commonly used to allow threads to wait on a *condition* to be true: consumers *wait* until a producer *signals* that something happened

Condition Variables - `L.Lock()`, `L.Unlock()`, `Wait()`, `Broadcast()`, `Signal()`

- `cond := sync.NewCond(&sync.Mutex{})`

- `cond.L.Lock()`
- `cond.Wait()`

- Call L.Lock() before Wait()

- Insert calling goroutine in queue and block (wait)
- Calls L.Unlock()

- `cond.Broadcast()`

Unblock *all* the goroutines in (and remove them from) the waiting goroutine queue

- `cond.Signal()`

Unblock the head goroutine in (and remove them from) the waiting goroutine queue

- Blocked routines go back to running state
- Invokes cond.L.Lock() (in the resumed cond.Wait() call) to try to acquire and hold the lock cond.L again
- cond.Wait() call exits after the cond.L.Lock() call returns

Condition Variables - Example

- Review the following example

- https://go.dev/play/p/8Am51UxjSVS

sync.Cond – Always Check the Condition!

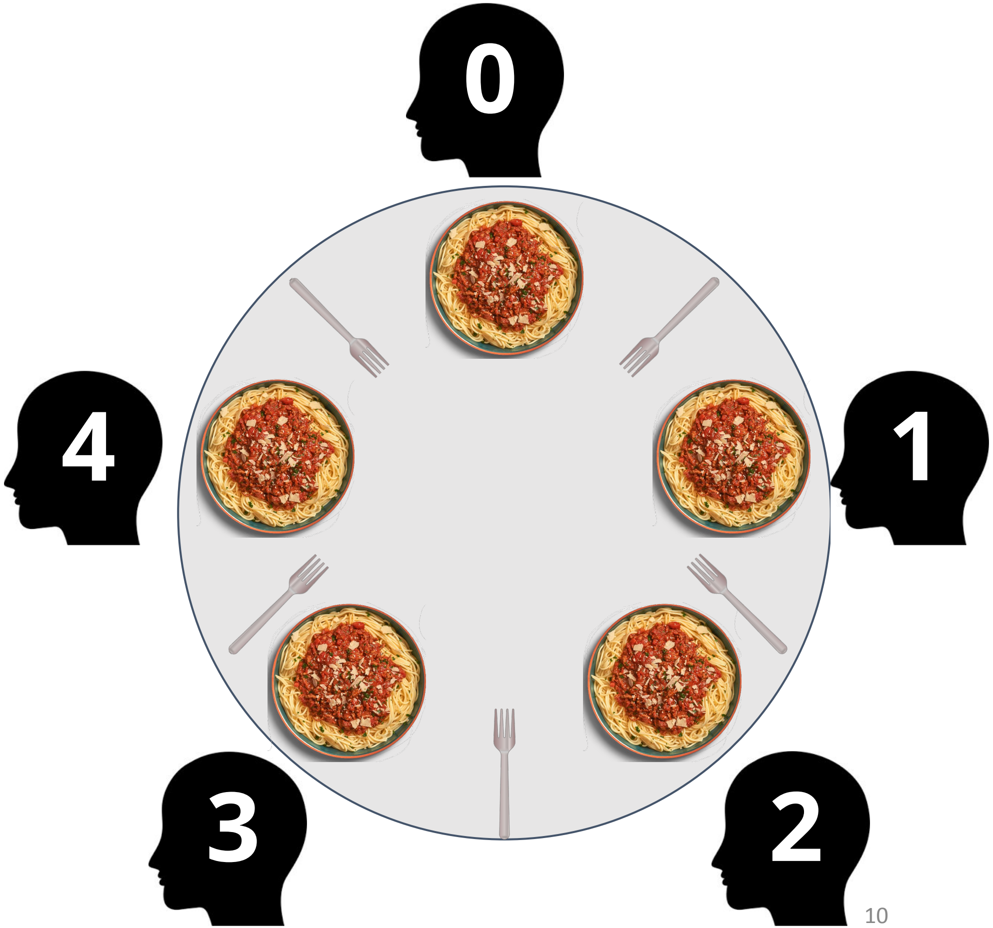
- Why is this loop here?
- `cond.Wait()` does not guarantee the condition holds when it returns
- The condition could have been made false again while the goroutine was waiting to run
- Always check the condition, and keep waiting if it does not hold

```
checkCondition := func() bool {
    // Check the condition
}

for !checkCondition() {
    cond.Wait()
}
cond.L.Unlock()
```

Dining Philosophers

- Classic problem that illustrates issues related to synchronization
- Models concept of multiple processes competing for limited resources
- Formulated by E.W. Dijkstra
- Framework:
  - Five philosophers seated at a table
  - Infinite cycle of thinking and eating
  - Philosopher must pick up <u>**both**</u> forks in order to eat
  - Determine policy / algorithm so that each philosopher gets to eat and does not starve



Dining Philosophers Policy

- The philosophers require a shared policy that can be applied concurrently
- The philosophers are hungry! The policy should let everyone everyone eat (eventually)
- The philosophers are utterly dedicated to the proposition of equality: the policy should be totally fair
- Discuss - what can go wrong?

Dining Philosophers - Solution 1

```
type Philosopher struct {
	name  string // name of philosopher
	left  int    // fork number on the left
	right int    // fork number on the right
}
func (p *Philosopher) Dine(table []sync.Mutex) {
	for {
		p.Think()
		table[p.left].Lock()
		table[p.right].Lock()
		p.Eat()
		table[p.right].Unlock()
		table[p.left].Unlock()
	}
}
```

```
func main() {
	philosophers := []*Philosopher{
		&Philosopher{"Michelle", 0, 1},
		&Philosopher{"Bill",     1, 2},
		&Philosopher{"Sonia",    2, 3},
		&Philosopher{"Brooke",   3, 4},
		&Philosopher{"Eric",     4, 0},
	}
	table := make([]sync.Mutex, len(philosophers))
	for _, philosopher := range philosophers {
		go func(p *Philosopher) {
			p.Dine(table)
		}(philosopher)
	}
}
```

Solution 1 - Demonstration

- Run the program:
  - https://play.golang.org/p/bV0JhIhN9lt

- Notes
  - Math.rand does not produce random numbers on the the playground
  - Try running locally (copy and paste)

4 Necessary Conditions for Deadlock

- Mutual Exclusion
- Hold and wait
- No preemption
- Circular wait

Solution to Problem

- Dijkstra
    - Number the resources (forks) from 0 to 4
    - Process (philosopher) will always pick up the lower-numbered fork first, and then the higher-numbered fork

- Are there any problems with this approach?

References

https://go101.org/article/concurrent-synchronization-more.html

https://en.wikipedia.org/wiki/Dining_philosophers_problem#Resource_hierarchy_solution